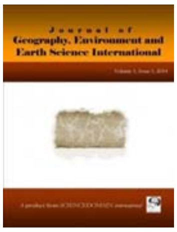

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Analysing Spectral Indices and Land use of Wayanad Wildlife Sanctuary, Kerala

P. Vineetha[1*], Rajesh Reghunath[2] and T. Neelakandan[3]

[1]Department of Geography, University College Thiruvananthapuram, 695034, Kerala, India.
[2]Department of Geology, University of Kerala, Thiruvananthapuram-695 581, Kerala, India.
[3]Department of Geography, University College Thiruvananthapuram, 695034, Kerala, India, (Retd: Head).

Authors' contributions

This work was carried out in collaboration between all authors. Author PV designed the study, performed the analysis, wrote the protocol and wrote the first draft of the manuscript. Authors RR and TN managed the analysis, read and approved the final manuscript.

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ABSTRACT

Geospatial tools play significant role in forest ecology and management, where vegetation indices and transformations have been extensively used for vegetation characterization. Hence, in this study, an attempt has been made to characterize the various hydrologic regimes in Wayanad Wildlife Sanctuary, Wayanad district, Kerala using geospatial tools. The study area was focused on Muthanga , a part of the Wayanad Wildlife Sanctuary of Wayanad district, Kerala with an area of 87.13 km^2, where the major vegetation types are moist deciduous with a few scattered patches of evergreen and forests plantation. Out of the many spectral indices employed in the hydrologic studies of the forest areas, tasseled cap wetness index, Normalised Difference Vegetation Index (NDVI) and Normalised Difference Water Index NDWI were used in this study. Since topography also affects the hydrological processes by controlling the spatial distribution of soil moisture in a realistic way, some of the terrain indices, e.g., topographic wetness index (TWI) were also employed in the present study. Statistical analysis was conducted in order to unravel the

**Corresponding author: E-mail: geo.vineetha@gmail.com;*

relationship between vegetation types and hydrology. The results of the analysis suggest that geospatial tools are efficient in hydrological characterization of forested vegetation of the region, which compared the wetness of the region using a variety of parameters with their corresponding vegetation.

Keywords: Forest vegetation; spectral indices; Wayanad WLS.

1. INTRODUCTION

Management of natural resource like forest needs periodic surveys and inventories for comprehensive studies. As the traditional inventory strategies (field observations, analysis of aerial photographs) are cost-intensive and time-consuming, multispectral remote sensing data seem to be attractive to complement and optimize forest inventories. Spectral indices are now a day's very commonly utilized in remote sensing studies. They are the combinations of spectral reflectance from two or more bands /wavelength from a multispectral imagery. Among the spectral indices Vegetation indices are the most popular which describes the vegetative cover, its greenness, density and health of the vegetation. Vegetation indices and transformations have been extensively used for vegetation characterization and mapping in forest ecological studies. The spectral analysis is the extraction of quantitative information from the reflectance spectra of earth features. Spectral and terrains indices are the major analytical techniques used in this direction. Forest species appear to vary greatly in chlorophyll and biomass reflectance as a function of plant species and hydrologic regime [1]. Generally many forested areas include several physiographically different areas which differ in their hydrological regimes, and therefore, in their vegetation types [2]. The spatial relation of soil moisture and Normalised Difference Vegetation Index (NDVI), which is a common vegetative index that open up the possibility to use satellite soil moisture data to predict vegetation dynamics was also identified [3]. NDVI and Normalised Difference Water Index (NDWI) has been compared to analyze the moisture content in scrubland [4]. Surface water mapping was done using NDWI index from Landsat imagery in Yangtze River Basin and the Huaihe River Basin in China. [5]. The role of Tasseled cap wetness Index in forest disturbance has been analysed in northern Maine, USA [6]. By evaluating Digital Elevation Model (DEM) ,Topographic Wetness index (TWI) has been examined for studying soil wetness of the Krycklan catchment in North Sweden [7]. Satellite data acquired across temporal and spectral ranges facilitate the study of various aspects of vegetation [8]. The present study focuses on the comparison of hydrologic regimes of different types of vegetation in the Muthanga, a part of the Wayanad Wild life Sanctuary.The objective of this study include finding out the relationship between vegetation types of the area under study with hydrology regimes of the area. With a few selected parameters of wetness here an attempt has been made to differentiate the types of vegetation and their associated hydrologic regimes. By adding more suitable parameters of wetness, more accuracy of the result could be ensured.

1.1 Study Area

Wayanad is an extensive table land encompassing Wayanad Wild Life Sanctuary (WLS). Wayanad WLS is contiguous to the protected areas of Nagarhole and Bandipur of Karnataka on the north-east and Mudumalai of Tamilnadu on the south-east. Wayanad WLS is bio-geographically one of the richest tracts of peninsular India with an undulating terrain and the altitude ranges from 650 to 1158 meters. It is rich in bio-diversity and is an integral part of the Nilgiri Biosphere Reserve, a UNESCO World Heritage site with four ranges namely Sulthan Bathery, Muthanga, Kurichiat and Tholpetty. There is high density of human settlements within the protected area. Wayanad Wildlife sanctuary is significant because of ecological and geographic continuity with other protected areas offering a unique eco system enriched with wildlife, forming natural corridor for the seasonal migration of long ranging animals within the greater conservation unit. The study area is fed by Noolpuzha which is one of the important tributary of Kabani river which originates from the eastern border of Wynad and flows towards north to join the Kabani river outside the Kerala State boundary.

Muthanga with a latitudinal & longitudinal extend of 11º40'2.66"N, 76º22'28.17"E have an aerial extent of 87.13 sq km.(Fig. 1) Almost the entire Wayanad district is drained by Kabini and its three tributaries, the Panamaram, Mananthavady, and Kalindy rivers. The mean yearly rain fall is 2322 mm. Lakkidi, Vythiri and Meppadi are the high rainfall areas in Wayanad. The mean maximum and minimum temperature for the last five years were 29ºC and 18ºC respectively. This place experiences a high relative humidity which goes even up to 95 percent during the south west monsoon period. Vegetation types include semi-evergreen, moist deciduous and dry deciduous forests. The moist deciduous forest of Muthanga is blessed with varieties of trees and other plants. The plantation crops grown in the cool climate includes coffee, eucalyptus, teak, arecanut, tea, etc. Mentioning about the geology of the region, the area mainly exhibits mainly two types of rock types ie,charnockite group of rocks and peninsular Gneissic complex (Fig. 2).The oldest rocks so far dated in Kerala are charnockites which yield U-Pb zircon age of 2930±50 Ma . The central and northern parts of Kerala are mainly covered with charnockites. Bulk of the rock formations in Kerala belongs to charnockite and associated gneisses and is well exposed in the hill ranges of Western Ghats. Charnockites of Kerala range in composition from acid to basic. The rocks of Peninsular Gneissic Complex are exposed mainly in the northern part of Kerala adjoining Karnataka. The rocks include hornblende biotite gneiss, biotite hornblende gneiss, foliated granite and pink granite gneiss [9].

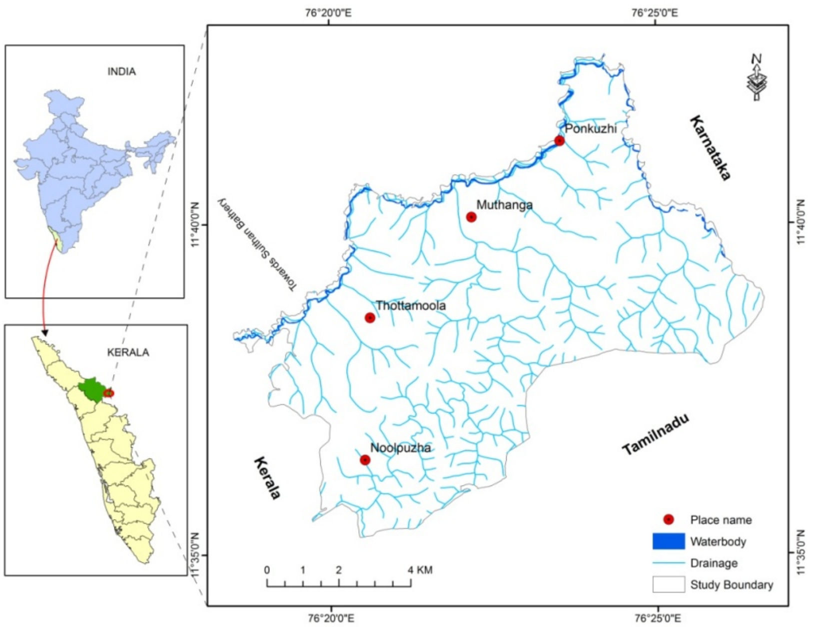

Fig. 1. Muthanga WLS, Wayanad, Kerala

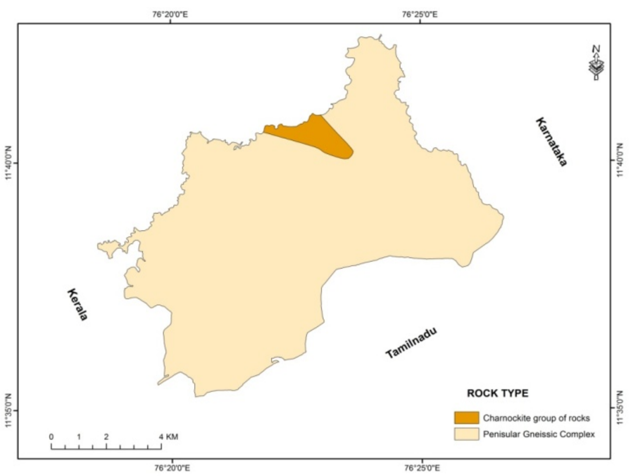

Fig. 2. Geology map of Muthanga WLS, Wayanad, Kerala

2. MATERIALS AND METHODS

2.1 Data Used and Analysis

The data for the present study includes Landsat Operational Land Imagery (OLI) data (11 bands, 30 m spatial resolution) dated 23rd December 2016 and the ASTER GDEM (30 m). The rationale behind the selection of the particular data includes the nearly global coverage, well calibrated and processed data and free availability. The software used for the study include ArcGIS 10.3 for data analysis and Erdas Imagine 2013 for generating spectral indices and classifying the satellite imagery .In this study hydrological regime refers to variations in the state and characteristics of wetness of a region which are regularly repeated in time and space. Spectral indices and the terrain indices are utilized to find out the hydrologic regimes of different vegetation types. Spectral indices are combinations of surface reflectance at two or more wavelengths that indicate relative abundance of features of interest. Spectral indices like Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Tasseled Cap Wetness Index (TCWI) have been calculated along with the terrain index Topographic Wetness Index (TWI) (Table 1). For generating each of the indices in Erdas Imagine software, the raster tab under the classification group was used. From that the NDVI tool was chosen and the appropriate input bands were selected for creating each of the indices. Different indices are listed depending on the data type .So selecting the desired index method will generate a spectral index from the given input. The contents of this list depend upon the sensor that is selected. Using this technique all the desired indices were generated with the following equations.

Normalized Difference Vegetation Index (NDVI): is an array of values derived from satellite data which is useful for vegetation mapping. It is one of the most widely used vegetation indices [10]. The NDVI value ranges from -1 to +1, where +1 describes the dense vegetation. As the study area is devoid of any open water body the NDVI value starts from 0, which shows the positive value.Here the NDVI value ranges from 0 - .82, which means the area represents mainly vegetative parts represented in red colour (Fig. 3)

Normalized Difference Water Index (NDWI): of McFeeters [11] and the modified version of Xu [12] is used to achieve the signature differences between water and other targets through analyzing signature features of each ground target among different spectral bands, and then to delineate land from open water. Here, +1 signifies the presence of extensive deep water bodies and -1 is for vegetation cover. That is, the NDWI value for water areas will be > 0 where as it will be < 0 for non water areas. Here the value of NDWI ranges from -1 to 0.082.The wetter regions are highlighted in red colour. (Fig. 4)

Tasseled cap transformation (TCT): is a linear transformation which reduces overlapping of multi-spectral datasets into fewer number of image based on particular scene characteristics [13]. The present study concentrates only the wetness image of TCT to extract the wetlands In this map the red colour regions represents the areas under moisture content with a value ranging from -0.115 to 0.054. (Fig. 5)

Table 1. Spectral indices used and their definitions

Sl. no.	Index/Parameter	Definition
1.	Normalized Difference Vegetation Index (NDVI)	***NDVI* = R_{NIR} -R_{RED} /R_{NIR} + R_{RED}** Where R_{NIR} and R_{RED} to bands 5 (0.85 - 0.88) and 4 (0.64 - 0.67µm) of Landsat (OLI) data respectively
2.	Normalized Difference Water Index (NDWI)	***NDWI*= R_{NIR} -R_{SWIR}/ R_{NIR+} R_{SWIR}** Where R_{NIR} and R_{RED} to bands 5 (0.85 - 0.88) and 6 (1.57 - 1.65) of Landsat (OLI) data respectively
3.	Tasseled Cap Wetness Index (TCWI)	**(0.1511*B2)+ (0.1973*B3)+(0.3283*B4)+ (0.3407*B5)+ (-−0.7117*B6)+ (−0.4559*B7)** where B2 to B7 are the DN values of the respective bands of Landsat (OLI)
4.	Topographic Wetness Index (TWI)	**TWI=(*a*/tanB)** a = Upstream contributing area in m^2, i.e. catchment area. B=SLOPE

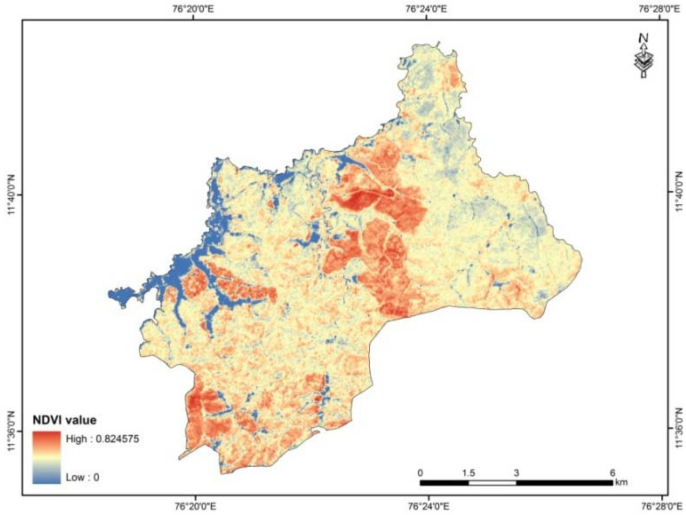

Fig. 3. Normalized difference vegetation index

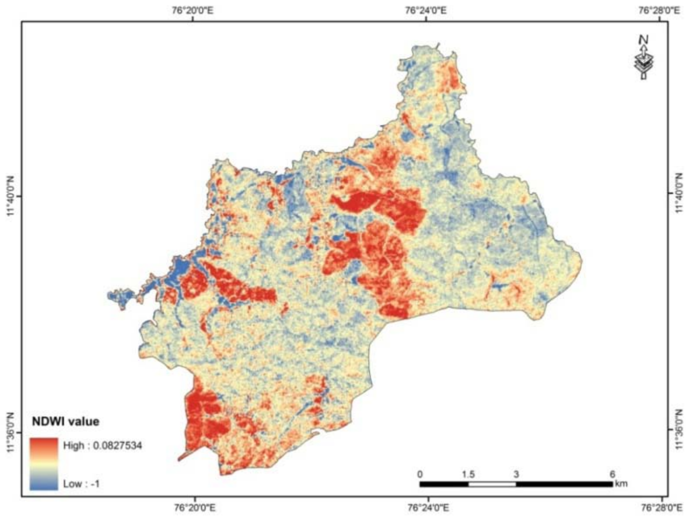

Fig. 4. Normalized difference water index

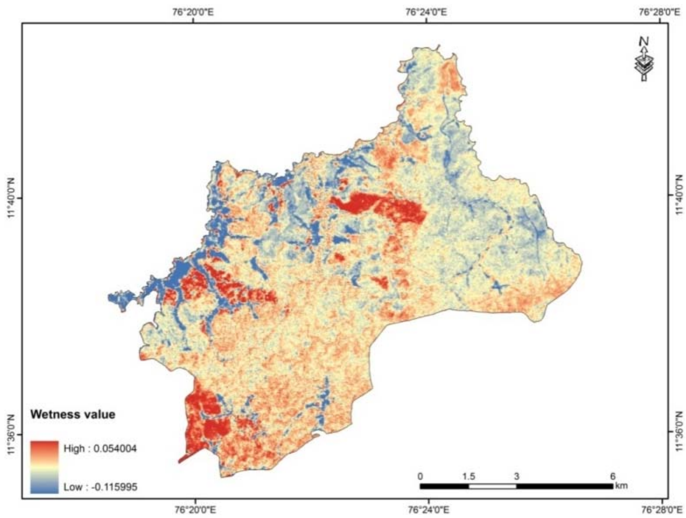

Fig. 5. Tasseled cap wetness index

Topographic Wetness Index (TWI), also called Compound Topographic Index (CTI) is a steady-state wetness index derived from ASTER Dem. TWI can be used to describe the spatial distribution of the soil moisture and related landscape processes. A high TWI indicates areas were much water accumulates and the slope is low. In contrast, steep slopes drain water and are therefore drier as indicated by low TWI [14]. The red indicating regions in the map shows the steady state wetness region with the values ranging from 3.64 to 21.59.(Fig. 6)

Using these spectral indices the parameters were derived and a land use classification of the area was done using the supervised classification method comprising five vegetative classes. (Fig. 7) namely Agriculture, Mixed forest, Grassland, Plantation (eucalyptus) and Dense forest. The classified vegetative classes are compared and sampled with their corresponding spectral as well as the terrain indices to give the different hydrological regimes or units. The pixel value of the particular vegetation type is compared with the same pixel in spectral and terrain indices.

The parameters NDVI, NDWI, TCWI and TWI were sampled against the land use using the sample tool function available in the Spatial Analyst tool in ARCGIS 10.3 .Here the values of each parameter are identified for each vegetation type. The value of each parameter to a particular vegetation type is compared further with

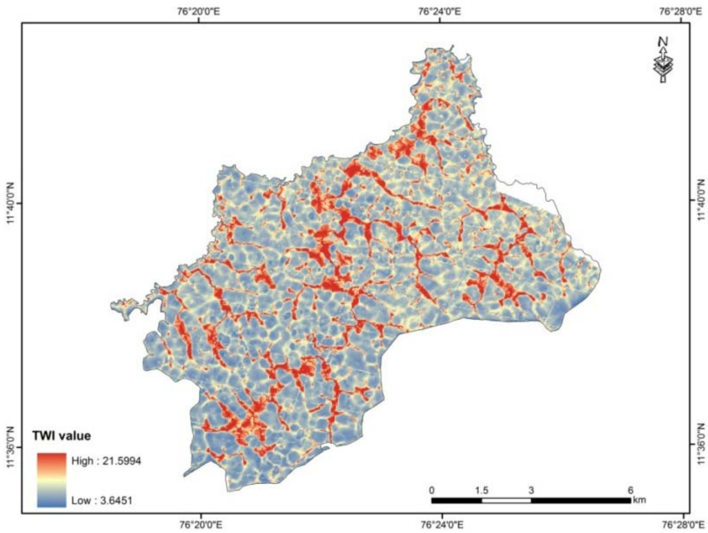

Fig. 6. Topographic wetness index

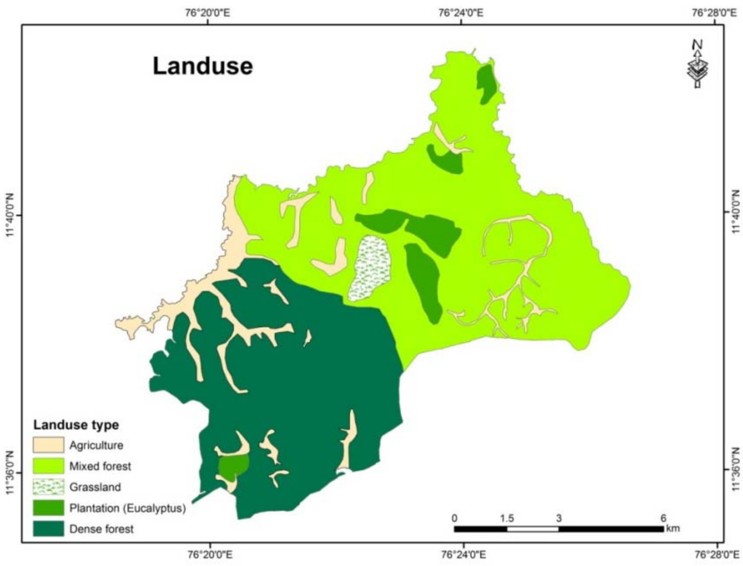

Fig. 7. Landuse classification

statistical analysis for finding the relation between the vegetation type and each parameter's corresponding wetness status.

2.2 Statistical Analysis

Statistical analysis using discriminant function analysis was done to assign the group means or centroids of each of the parameter to a particular vegetation type. This function help to assign data to one or more groups which helps in identifying the pattern recognition. The group centroid means are calculated to understand how far the parameter group differs from each other to a particular vegetation type.

3. RESULTS AND DISCUSSION

The Normalised Difference Vegetation Index analysis displays the value ranging from 0 to 0.82, clearly points out that the area is flourished with vegetative cover. The highest value exhibits the dense forest while the values close to zero shows other types of vegetation such as mixed forest, grassland and plantations. From the Normalized Difference Water Index analysis, the wetter portions of the study area showing a value range of -1 to 0.08 displays the dense forested tracts in the region. The Tasseled Cap Transformations reveals the moisture-laden areas with a value ranging from -0.11 to 0.05.Here the dense forest type shows the wetter portions. The Topographic Wetness Index which is commonly based on topographic control, used in hydrological processes indicates value ranging from 3.64 to 21.59 .The higher values express the moist region which is highly depended on topographic slope of the area unlike another vegetative index. From these vegetation indices and topographic index the wetter or moisture regions has been unveiled along with its vegetative types and a detailed hydrological character of the area has been analyzed. Considering all of the vegetative indices and topographic index the land use of the region has been compared. From the statistical analysis the group centroid diagram (Fig. 8) was created. The vegetation types from the land use were assigned with the codes starting from 1 to 5,ie, code 1(Agriculture),2 (Mixed forest),3 (Dense forest),4 (Grassland) and 5 represents Eucalyptus plantation**.** Each group centroid represents particular vegetation with a particular code as discussed above. The placement of the group centroid exhibits the hydrological character of the area. While analyzing the group centroids, out of the five vegetation centroids the Code -1, (agriculture) shows a significant change in its hydrological unit compared to others. Agriculture, which is man-made vegetation type exhibits a different hydrological unit compare to other vegetative units. Code 5 (Eucalyptus plantation), also exhibits slight difference when compared to other vegetative units. Eucalyptus plantation is often linked to high water use relative to other species [15] and it consumes more water for its growth when compared to other trees which shows a distinct unit. But the Code 2, 3 & 4 (Mixed forest, Dense forest & Grassland shows almost similar hydrological regimes as these groups belongs to the natural forest community. While discussing about the hydrology of the region,the area is drained by Noolpuzha, one of the tributary of Kabani River, which is

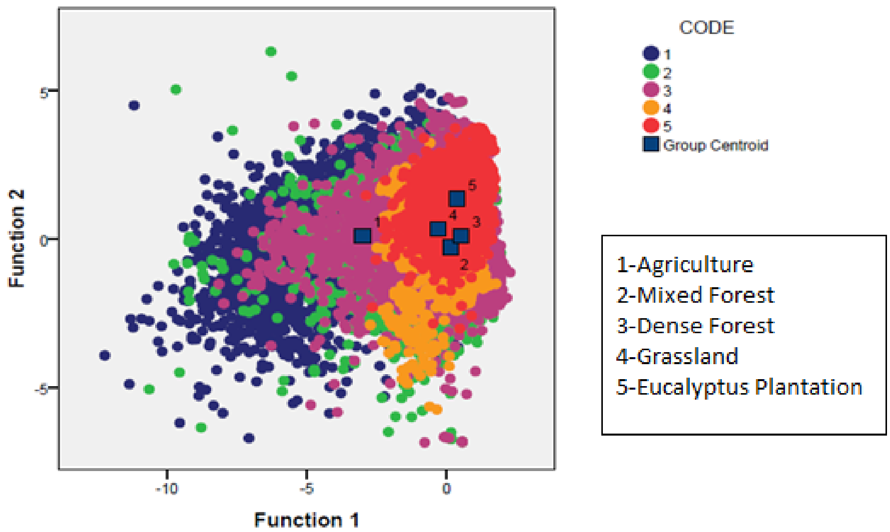

Fig. 8. Parameter group Centroid diagram

situated on the northern and eastern fringe area of the study area. The tributary and the associated streams have an important influence on the land use of the area and the resultant hydrological units or regimes.

The area wise delineation of land use vegetation type has been discussed (Table 2) the agriculture and the Eucalyptus plantation which shows a distinct hydrological unit covers an area of 8.01 and 4.59 sq km respectively. The majority of the forest type belongs to dense forest which is 53.42 sq km. The mixed forest comes second in the area covering 40.95 sqkm. The least covered area of the land use is grassland which is 1.55 sqkm .

Table 2. Land use type and the area covered

Forest type	Code	Area in sq km
Agriculture	1	8.01
Mixed forest	2	40.95
Dense forest	3	53.42
Grassland	4	1.55
Eucalyptus plantation	5	4.59

4. CONCLUSION

Vegetation types of the area have been compared with the help of various wetness parameters like NDVI, NDWI, TCWI and TWI of the vegetation. It is found that the man-made vegetation unit exhibits a noticeable difference in its hydrological response. Thus the study highlights a distinction between man-made and natural hydrological regimes. Assessing the land use of the area, it is found that dense forest had a majority over the other land use type in its area and the grassland exhibits the least. As the area is well drained by one of the important tributaries of Kabani River which is Noolpuzha, it is clear that the area is hydrologically stable and the obtained results is also influenced by the hydrology of the area. The present study intends to make a distinction between the hydrological units of the land use types using remote sensing based spectral indices. The accuracy of the obtained results could be improved by adding more advanced suitable parameters.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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